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FROM

Professor W. M. Davis

25 Feb. 1890

THE

MODERN LAW OF STORMS.

BY

EVERETT HAYDEN,

MARINE METEOROLOGIST, UNITED STATES HYDROGRAPHIC OFFICE,
WASHINGTON, D.C.

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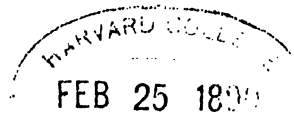

Prof. W. M. Davis

THE MODERN LAW OF STORMS.

By the term "Law of Storms" is meant, as sailors understand it, a code of rules or directions for manœuvring a vessel so as to avoid the centre, or most dangerous portion, of a storm, and, as a secondary consideration, to take advantage of its favorable winds to prosecute the voyage. To a landsman it is difficult to appreciate the many and varying considerations that enter as factors in this question. Here on land our position is fixed; we take storms as they come, and make the best of it. It is hardly once in a lifetime that an approaching storm threatens us with danger to life or limb, and all that is required of the average individual is to "know enough to go in the house when it rains." Moreover, the great weather bureaus that are now established in the leading civilized nations, although a natural and legitimate growth, have a certain tendency, like other great monopolies, to crush out individuality, especially anything that may look like opposition. At sea, however, the case is widely different. The navigator is thrown upon his own resources entirely. He must decide from his own unaided observations whether a storm is approaching, and, if so, whether it is likely to be of dangerous severity. He must then, first of all, try to avoid the most dangerous regions of the storm-field, allowing a fair margin for safety; to do this, he has to consider the character of his vessel, the amount of sea-room he has for manœuvring (that is, the lay of the land, considered with reference to the winds and currents to be expected), the bearing and distance of the storm-centre, and the size, severity, velocity, and track of the storm. Secondly, he has to decide how he can best profit by the approaching storm to continue his voyage; to do this, he must understand the general character of the wind system, the probable track of the storm relative to his vessel's track, and the character of wind and weather following. Thus the law of storms is a very different thing to the practical navigator from what it is to the meteorologist, and in this article I shall confine my attention wholly to the practical side of the question.

It is rather astonishing, at first thought, to see how apparently slight are the modifications that the progress of the past fifty or sixty years has made in the old law of storms, as discovered by Redfield and enforced by Reid, Piddington, Thom, and other early writers. The

essential features of the old law were as follows: A hurricane is a "revolving storm,"—that is, a whirlwind (as opposed to a "straight-line gale," where the wind blows from the same compass-point over a large region, and for a long time); the rotation of the whirlwind is *against* watch-hands in the northern hemisphere, and *with* in the southern; the storm, whirling about a centre, has also a progressive motion along a parabolic track, westward in the tropics, receding gradually from the equator, and, finally, moving eastward in higher latitudes. Upon these general considerations—soon acknowledged to be very important facts, or, at least, very close approximations to the truth—a simple code of rules was based for the guidance of navigators, differing in the two hemispheres according to the different conditions of rotation and progressive motion. The first and most obvious rule is that the centre, or most dangerous portion of the storm, lies in a direction at right-angles to the direction of the wind at any position in the whirl; this is the well-known "eight-point rule." Next comes the rule regarding the tack upon which a vessel ought to lie-to in order to ride out the storm,—that is, let it pass over her with as little danger as possible. It is very difficult for any one to appreciate the importance of this question unless he can realize vividly the tremendous force of wind and sea in a hurricane, the sudden and terrific shifts of wind, the danger a vessel is in when taken aback, and, finally, the difficulty—impossibility, in most cases—of wearing ship (in order to change the tack) when once caught in such a storm. The rule is to lie-to on the *coming-up* tack,—that is, the tack on which the vessel will come up to the wind as it shifts, and not get taken aback. The great value of this rule is that it is so simple and universal in its application, and that there are so few exceptions. The conditions are such that if the wind begins by shifting to the right, say, for example, from east to east-southeast, and the vessel lies-to on the right, or starboard, tack, the next shift will also be to the right, say to southeast, almost invariably,—that is, the wind will continue to shift aft and not come out ahead. The best example of the results that may follow a failure to observe this rule is the disaster that befell Rodney's fleet and prizes—in all some ninety-two vessels—off the Grand Banks in 1782: all preparations for bad weather were made and the fleet hove-to, but on the *wrong tack;* frigates, prizes, and convoy were dismasted, sunk, scattered, abandoned; every man-of-war but one foundered, and more than three thousand lives were lost. The other rules of the old law of storms follow directly, you may say, from these two, together with the facts already mentioned concerning the circular character of the storm and its progressive motion along a curved track. Thus, if it be known from the appearance of the weather, sea, etc., that a revolving storm is approaching, and the wind freshens but remains steady in direction, it follows that the vessel is directly on the track of the storm, and that

she should square away and run before the wind, keeping her compass-course (when the wind begins to shift) until obliged to lie-to, when she should lie-to on the coming-up tack, as before.

One other point regarding the old law of storms, and this, like the law of the coming-up tack, is as important to-day as it was fifty years ago: the storm disk is divided, for convenience of reference, into two semicircles, called, respectively, the manageable (or navigable) and the dangerous semicircle. Subsequent reflection and research have, to be sure, added somewhat to the value and force of these terms, but this only confirms the value of their original signification. In preparing data regarding West Indian hurricanes for Hydrographic Office publication No. 86 (Caribbean Sea and Gulf of Mexico; Washington, 1888), I defined the dangerous semicircle as follows, referring, of course, to northern hemisphere storms:

"When the storm is moving to the westward, that portion lying north of the track is the dangerous semicircle, and while moving in a northerly direction, the portion to the eastward is the dangerous semicircle. In other words, the right-hand semicircle is by far the more dangerous portion of the storm, and for three reasons: First, because the progressive motion of the storm along its track (about seventeen miles an hour) increases the velocity of the wind in this semicircle, while decreasing it by the same amount in the other semicircle; secondly, because both wind and current tend to carry the vessel directly in front of the storm, and if obliged to scud she will run into still greater danger; and, finally, because this is the side towards which the track is liable to recurve at any moment."

Without going into the history of the development of these important laws in the hands of the numerous writers who have, at various times and among various nations, sought to verify, extend, and complete them for the benefit of commerce, let me advance at once to what I have called, in the title of this article, the modern law of storms. By this I mean to cast no discredit upon the old, but to consider briefly the few thoroughly well-established modifications of and additions to these laws that have already become a permanent and essential part of the code, and must be so recognized in treatises on navigation, examinanations for officers' licenses, and courts of admiralty.

No reference to this subject would be complete at the present day without mention of and acknowledgment to Hon. Ralph Abercromby, the eminent English meteorologist who has made a specialty of this practical side of the question, and to whom the thanks of every meteorologist and practical navigator are due for his masterly and exhaustive researches. His knowledge is not that of books and theories alone, but in the prosecution of studies regarding the handling of ships in hurricanes he has made a tour of the world, visiting every hurricane region of the globe with but one exception, and that, unfortunately, a very important exception, the West Indies. He has thus met the leading local authorities, talked with them regarding their views and the local peculiarities of their storms, consulted and studied their

original and unpublished data, and, armed with a thorough knowledge both of the scientific and practical sides of the question, has given us a most important and valuable *résumé* of the best modern practice. It is rather an amusing fact that during his extended tour of the world he did not have the good fortune (as he puts it) to encounter a single hurricane, much as he desired to do so. After reviewing the subject very thoroughly, Abercromby gives his conclusions as follows, comparing his revised rules with the old ones:

"It will be remarked:

"1. That the rule for finding approximately the bearing of the vortex is modified and improved by the addition of indications derived from clouds; but that still the position of the vortex cannot be determined nearly so accurately as was formerly supposed.

"2. That the great rules of the 'laying to' tacks remain unaltered.

"3. That the greatest improvement is in recognising the position and nature of the belt of intensified trade wind outside the true storm field of a cyclone, where a ship experiences increasing wind without change of direction, with a falling barometer. The old idea that such conditions show that a vessel is then necessarily on the line of advance of a hurricane is erroneous. She may, but she need not be; and under no circumstances should she run till the barometer has fallen at least $\frac{4}{10}$ths inch.

"4. There are certain rules which hold for all hurricanes; but every district has a special series, due to its own local peculiarities.

"Finally, no one should blame the master of a ship for not following the established rules without the closest investigation, for, as Piddington says, 'absolute rules are all nonsense,' and much depends upon the capabilities of a ship and on the ever-varying conditions of a heavy cross sea."

It will thus be seen how apparently slight are the modifications that the experience of half a century has made in the sailor's law of storms. But although these modifications are apparently slight, they are really of very great importance, and very often, in critical cases, may turn the scales between safety and disaster. For a full discussion of the subject, both as to general rules for all hurricanes (both hemispheres) and special rules for each hemisphere and particular regions (notably the South Indian Ocean), I cannot do better than refer the reader to Abercromby's paper in the *Journal of the Scottish Meteorological Society* (Third Series, No. VI.). Within the limits of this article I can only touch very briefly upon what I regard as points of especial importance.

First, then, regarding the bearing of the centre of a hurricane, as estimated by means of observations at a single ship or station.

Here a decided advance seems to be the general recognition of the early indications of an approaching hurricane. No doubt individual navigators were thoroughly posted in this matter years ago, but at present the symptoms are so well known and so clearly stated in all works on the subject that every one must be familiar with the leading facts, applicable alike to hurricanes in every ocean, whether north or south of the line. Let me quote from the "Pilot Chart of

the North Atlantic Ocean," where these important general rules are printed every month, and thus kept conspicuously before the navigator:

"*Earliest indications:* Barometer above the normal, with cool, very clear, pleasant weather; a long, low ocean swell from the direction of the distant storm; light, feathery cirrus clouds, radiating from a point on the horizon where a whitish arc indicates the bearing of the centre.

"*Unmistakable signs:* Falling barometer; halos about the sun and moon; increasing ocean swell; hot, moist weather, with light variable winds; deep red and violet tints at dawn and sunset; a heavy, mountainous cloud bank on the distant horizon; barometer falling more rapidly, with passing rain squalls."

The value of such early warning is of course very great, and all the more so if considered in connection with the probable path of the storm, as indicated by special experience or researches regarding the storms of the particular ocean where the vessel may be. A steamer can readily alter her course and avoid the storm, even though it require a wide détour; a sailing vessel is often unable to do so, owing to the light variable winds that she is liable to encounter; but she can at least make all preparations, and, by watching carefully every change of bearing of the distant cloud bank, be ready for instant and decided action when the winds of the cyclone itself first reach her. Nothing could be more graphic and interesting, as illustrating the unmistakable character of these early indications of the approach of a hurricane, than the many reports that are sent in to the Hydrographic Office by masters of vessels. The following may be quoted, by way of illustration: Captain Taylor, of the British ship "Argus," encountered a typhoon off the coast of China last August, and in his report he states as follows: "For two days previous the weather was hot and sultry, with calms and light variable winds. The wind at night had a hot and oppressive feeling. A swell rising from the southeast, and gradually increasing until very heavy. August 21, 4 P.M. (lat. about 27° N., long. 124° E.), a dense bank arose in the east-southeast, and the sky had altogether a troubled appearance, light olive-colored clouds scudding very low, with great speed. The barometer previous to this had kept very steady; it now fell. At sunset the sky had a fearful appearance,—a heavy blue-black cloud at an altitude of 10° to 15° above the horizon, having thin edges tinged with a deep crimson border, as if bound by a ribbon of that color, and in the southeast the sky was a lurid red, casting a reflection on the sails and over the water, which at that time was calm, with a heavy swell."

Again, take the case of the St. Thomas-Hatteras hurricane of last September: hundreds of vessels off our coast and about Bermuda noted the long, low ocean swell from the southward, increasing day by day, overspreading the entire western Atlantic, rolling in upon the sandy beaches from Florida to Long Island and breaking upon the granite ledges at Newport and along the coast of Maine and Cape Breton. Captain White, of the American schooner "Ada Bailey," was ninety

miles north-northeast from Hatteras, September 2, and at that early date noticed a heavy swell heaving in from east-southeast, evidently from the great hurricane that only reached St. Thomas the following day. That it really came from this distant storm is evidenced by many other reports, and by his own journal of subsequent dates, "September 3, lat. 37° 07′ N.; long. 74° 21′ W., a long and heavy swell from east; weather looking very bad. September 4, no wind; temperature of air, 84°; very heavy swell from east-southeast. September 5, lat. 37° 20′ N.; long. 72° 38′ W., calms; a long and heavy swell from south-southeast; every appearance of a hurricane."

Here was a vessel within a short distance of Hatteras, watching, by means of her own unaided observations, the slow but steady and unmistakable approach of this great hurricane *six days* before it reached the coast, and actually a week, to a day, before it finally secured recognition by the display of a cautionary signal for the benefit of commerce! At first thought it would seem to be a good idea for vessels to signal to the shore and communicate early warnings of approaching storms, rather than the reverse; but the fact is that a skilled observer can so easily detect the approach of a hurricane and estimate its severity and track that, with half a dozen well-selected stations along the coast, it ought to be impossible for one to approach us without several days' warning. The *state of the sea*, for example, is a very important indication, and this might well be reported by all our coast stations and charted on the daily weather map, as is done already in England and France.

I may well refer here, between the earliest indications of a cyclone's approach and its actual arrival, to certain statements that I made in an article on Tropical Cyclones that appeared in this magazine last June (republished in the *Revista General de Marina*, Madrid, and the *Nautical Magazine*, London), based principally upon the long experience of Padre Viñes, of Havana. These considerations do not appear in Abercromby's paper, although, in my opinion, they might well do so. First, as to the size and character of the approaching storm: "Soon the beautiful feathery cirrus clouds appear: if somewhat faint and opalescent in tint, fading gradually behind a slowly thickening haze or veil, the approaching storm is an old one, of large area; it is coming, perchance, from the Cape Verde Islands, and has crossed the entire ocean on its westward journey. If the cirrus plumes are of snowy whiteness, projected against a clear blue sky, it is a young cyclone just growing into its full strength and fury,—an overgrown tornado." Also the following, as a guide to the character or severity of the storm,—whether or no it has reached the stage when it fully deserves the name of a hurricane: "I have already referred to the marked character of the atmospheric circulation that is specially indicative of a tropical cyclone, and this is one of the most important things to look out for. The whole thing may be very easily appreciated by

remembering that a cyclone of any great intensity is an *ascending spiral whirl*, with a rotary motion (in the northern hemisphere) against the hands of a watch. The surface wind, therefore, blows spirally inward (*not* circularly, excepting very near the centre); the next upper current (carrying the low scud and rain clouds) moves in almost an exact circle about the centre, the next higher current (the high cumulus) on an outward spiral, and so on, up to the highest cirrus, which radiate directly outward. This series of varying atmospheric currents—varying, not irregularly and at hap-hazard, but according to a fixed, definite, and invariable system—is one of the most invaluable symptoms that the approaching 'area of low barometer' (that hackneyed but useful term) has already reached the dignity of a hurricane. The angle of divergence between the successive currents is almost exactly two points of the compass. Ordinarily, with a surface wind from north, for instance, the low clouds will also come from north; on the edge of a hurricane, however, they will come from north-northeast *invariably*."

Now, to consider the method of estimating the bearing of the centre when a vessel is actually overtaken by the storm,—that is, when the characteristic fall of the barometer, flying scud, passing squalls of fine, misty rain, etc., show that the storm is upon her and that it will soon blow "great guns."

In this matter my own far less extensive experience only confirms to a marked degree what Abercromby says in the paper already referred to. This is something, however, inasmuch as my experience has been in the West Indies, and I have had the benefit of consultation with Padre Viñes, the undisputed authority in the one great hurricane region not visited by Abercromby. To state briefly, then, the leading rules, I would say, first of all, that *the incurvature of the winds in tropic cyclones, as in other storms, is now universally admitted, and the eight-point rule is an unsafe guide.* Nevertheless, as this old rule is so familiar and so difficult to displace in the esteem of many good sailors, it may help matters by putting it in this form, which is a much safer guide than the old way of applying it: *to use the eight-point rule as a guide to the bearing of the centre of a hurricane, apply it to the low clouds and not to the wind.* This follows directly from what has been said above as to the characteristic cyclonic circulation,—that is, "the surface wind, therefore, blows spirally inward (*not* circularly, except very near the centre); the next upper current (carrying the low scud and rain clouds) moves in almost an exact circle about the centre, the next higher current (the high cumulus), on an outward spiral, and so on, up to the highest cirrus, which radiate directly outward." To this the further very important addition should be made and remembered: *In rear of a hurricane the wind is still more strongly incurved, blowing almost directly towards the receding storm; here a ten-point or twelve-point rule is therefore a far safer guide, whether applied to the low clouds or to the wind.*

Cloud observations are justly regarded as of great importance by most modern writers on this subject, as the motions of the clouds give a more general and clearer view of the situation than any indications derived from the direction of the wind at a single station. Now the low clouds in a hurricane move at a height free from any complicating effect of surface friction, and they are therefore the best possible guide. The way the wind shifts in a hurricane is extremely characteristic: after a heavy squall the wind will blow very hard for a few minutes (or for some length of time, depending on the vessel's position, the velocity of the storm along its track, etc.), remaining steady in direction; then, with a fearful rush and roar, another squall will come along, bringing with it an instant shift of wind—say a point or two—when it will again blow steadily for a while from this new direction. It is as if the great whirlwind had such a grasp upon the ocean that the forces tending to move it bodily along its track had to drag it along by jumps, while it holds on "for all it is worth." In these terrific squalls you get a momentary touch, as it were, of the next upper current (the low-cloud current), and at that instant the old eight-point rule is no doubt a very close approximation to the truth. Let me quote a report to illustrate this more fully. The British steamship "Trinidad" was northwest of Bermuda, November 25 and 26, 1888, while the great hurricane of that month was central off Hatteras. Captain Fraser states in his report that "the barometer kept falling with the slowest possible motion, the wind hauling to the southward gradually. Heavy squalls of rain would bring the wind to the southward two or three points, but it would back farther to the eastward after the squall. The wind at Bermuda acted similarly." How is this to be explained? I take it to be as follows: The cyclone was moving about north-northeast very slowly; each squall gave for a moment a touch of the upper current (normally two points to the right of the surface wind), but after the squall the old surface wind-circulation was almost restored, on account of the slow movement of the storm. Thus this fact—a very important fact—might be inferred from such observations, even without the additional indication given by the very slow fall of the barometer.

I have left to the last what may be fairly called the most important of all the additions to the old law of storms, namely, the recognition of the fact that in the dangerous semicircle of every hurricane there is a broad belt in which the wind blows almost a "straight-line gale" towards a portion of the track of the storm, rather than somewhat radially towards a definite point on that track. This extremely important discovery I stated as follows in this magazine last June, and it will bear repetition here:

"Another very important fact (established by Meldrum, at Mauritius) may be stated thus: When a hurricane is moving along the equatorial limits of a trade-wind region, there is a belt of intensified trades to windward of its track; not until

the barometer has fallen about six-tenths of an inch is it safe to assume that, because the trade-wind increases in force and remains steady in direction, you are on the track of the storm. By attempting too early to cross its track, running free as soon as the wind begins to freshen, you are liable to plunge directly into the vortex of the hurricane."

Thus, for example, three vessels in the North Atlantic, on the same parallel and at intervals of a hundred miles, might have a strong northeast trade-wind, with every appearance of a hurricane to the south or southeast. As the wind increases and remains steady in direction, with a falling barometer, suppose each follows the old rule and runs with the wind on the starboard quarter,—or with the wind aft at first, keeping her compass-course if it shifts: the westernmost may, by good luck, cross safely ahead of the storm; the other two, however, are pretty sure to make an awful mistake and run into a position of the greatest danger. In other words, indisputable facts show that the only safe general rule in such a case is to wait till the barometer has fallen so decidedly that the case is desperate, and then, as a last resort, attempt to cross the storm track, if wind and sea will allow of it. It is at best a very dangerous expedient.

Now, it is very easy to take an imaginary case and argue against this rule,—to say, for instance, "If this vessel had run sooner, of course she would have had more time to get ahead of the storm, and her situation must have been infinitely better." But how about the other two vessels that acted in just the same way, under similar conditions, and yet could have done nothing worse if they had tried? No researches, no improvements, no experience, will ever enable every vessel to escape the fury of these storms. A vessel's position may happen to be such, relative to the hurricane, that no power on earth can save her. Again, by implicitly following a good rule—a rule that may save a dozen other vessels—a certain vessel may possibly get a little worse weather than she might otherwise have met with. But surely that does not vitiate the general rule. In fact, all that one can do—all that one should try to do—is to present the conclusions that the best authorities are agreed upon, with as many of the facts as possible upon which these conclusions are based, and leave the navigator free to form his own ideas, for it is upon his judgment that the final decision must depend, and upon his shoulders that the supreme responsibility must rest. We cannot expect to find any cast-iron rules that will never bend nor break under any strain. Huxley has well said that "science commits suicide when it adopts a creed." Certainly the master of a vessel who blindly follows a thumb-rule in navigation is liable, if not to commit suicide, at least to die a violent death. The fact is that here, as elsewhere, we cannot eliminate *brains* as a factor in our every-day life.

Let me propose here another addition to the law of storms, an

addition that may seem unscientific, but one that abundant testim proves to be one of the most important practical rules that the experience of the past fifty years has added to the old law: *Use oil to pr heavy seas from breaking on board your vessel.* In my opinion no treatise on the modern law of storms is complete without this addition, the value of which has been proved a thousand times in the last few years. For early recent mention of this invaluable aid to the safety of navigation, the public is indebted especially to the *New York Maritime Register.* Yet its world-wide recognition is generally attributed, both at home and abroad, to the wide publicity given to it by the facts that have been published from time to time on the monthly Pilot Chart of the North Atlantic Ocean.

"Seeing is believing," as the old saying has it, and I had a chance to see the truth of one of these new rules the 9th of September, 1888. We were in the Straits of Florida, on the eastern edge of a hurricane central in the gulf, a short distance west of the peninsula. The centre of the great cloud bank of the hurricane, with its piled up masses of towering, fantastically-shaped, leaden-colored clouds ("of hard, rolled, tufted appearance, like bales of black cotton"), bore about due west; the wind was south-southeast, and the low clouds flying overhead came from south: there must, I think, be few such clear, self-evident cases to prove the value of the new rules, or they would be accepted without the necessity of any argument. It happened to be my good fortune again, on November 24, of the same year, to notice the characteristic cyclonic circulation, cloud formations, etc., indicative of a hurricane of marked severity. This was in Washington, at about 2 P.M., and the rapid motion at the edge of the cirrus veil, directly overhead, first caught my attention; a moment's consideration of the other clouds, the surface wind, the dark-gray tint from overhead to the southern horizon, shading down towards a definite distant point where it was very dark, convinced me at once that there was a great storm off the coast. I called the attention of several friends in the office to the marked indications of a hurricane, and we saw from the morning weather map that the presence of a "low" area was indicated off the coast below Hatteras, although the data on the map gave very little indication of the actual severity of the storm. For weeks afterwards the papers were filled with accounts of the terrific experiences of vessels in that great November hurricane in which the steamship "Samana" and a dozen other vessels went down with all on board. I mention these two facts from my own experience to help support what I have said, and in the hope of communicating to the readers of this article at least a little of my own faith in the modern law of storms.

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HURRICANES

IN THE

BAY OF NORTH AMERICA.

BY

EVERETT HAYDEN.

READ BEFORE THE PHILOSOPHICAL SOCIETY OF WASHINGTON,
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Prof. W. M. Davis

HURRICANES IN THE BAY OF NORTH AMERICA.

BY

EVERETT HAYDEN.

[Read before the Society, October 12, 1889.]

The Bay of North America embraces the entire western part of the North Atlantic between Newfoundland and Venezuela, including the Caribbean Sea and Gulf of Mexico. The term was first used, I believe, by Prof. Alexander Agassiz,* and it is so expressive that it should come into more general use. In its general outlines this great body of water bears a certain analogy to the corresponding indentation of the North Pacific into the continent of Asia, and the hurricanes of the Bay of North America are very similar, in all their essential features, to the typhoons of the China seas. The tracks along which they move, however, seem to be far more uniform and regular in character, due, perhaps, to the greater simplicity in the general configuration of land and water and to the fact that the Gulf Stream, a famous breeder of ocean storms, is greater as to temperature, velocity, and volume than the Kuro Siwo, or Black Stream of Japan.

The word "hurricane" comes from a Carib word, meaning simply a violent wind. As used at present it has a double meaning: first, an entire storm system or cyclone, in which the highest force of wind is as high as 12 (Beaufort's scale); secondly, a wind as high as 12. Thus a sailor might say that on a voyage from Havana to New York he encountered a hurricane; here the word would mean a "revolving storm," or a very severe cyclone. Again, in describing the

* Prof. Agassiz's [illegible] Gulf Stream [illegible] Survey [illegible]

storm, the shifts of wind, &c., he might say that at 8 a. m. it was blowing a moderate gale from E NE.; at noon, a strong gale from E.; and at 4 p. m., a *hurricane* from SE.

A hurricane, then, in the broader signification of the word, is a cyclone of enormous intensity. This word *cyclone*, as originally coined by Piddington and adopted by Redfield and other early writers, and as still used by leading authorities, does not necessarily convey the idea of a violent storm, but is used as a generic term to refer to a wind system where the circulation is cyclonic (in the Northern hemisphere, *against* watch hands; in the Southern, *with*) and the barometric pressure below the normal. It is, I think, a pity that popular usage is making the meaning of the word too specific, somewhat as it has made the expression "tidal wave" too generic. The following quotation from Redfield is of interest in this connection:

"The term cyclone was first proposed by Mr. Piddington to designate any considerable extent or area of wind which exhibits a turning or revolving motion, without regard to its varying velocity, or to the different names which are often applied to such winds. If used in this sense it may prevent the confusion which often results from other names, more variable or indeterminate in their signification. Thus, all hurricanes or violent storms may, perhaps, be considered as cyclones or revolving winds; but it by no means follows that all cyclones are either hurricanes, gales, or storms. For the word is not designed to express the degree of activity or force, which may be manifested in the moving disk or stratum of rotating atmosphere to which it is applied. It often designates light and feeble winds, as well as those which are strong and violent."

The tracks that have been traversed by storms during each month of the year are valuable indications to the navigator regarding the probable path of a storm that he may encounter during a voyage. For this reason there were plotted upon the Pilot Chart of the North Atlantic Ocean last year

the tracks of all the cyclones on record for August, September, and October, respectively, likely to indicate to the navigator the paths that hurricanes usually follow during these three months—the especially dangerous hurricane months in the Bay of North America. Upon looking at these three charts it will readily be seen that the motion of translation of such storm systems is westward in the tropics, then northward into the temperate zone, and finally northeastward; it will be noticed, also, that the tracks are most numerous off our coast, in the Gulf Stream region. These storm tracks, although valuable as indicating in a general way the region where tropic cyclones are most liable to be encountered and the direction of their tracks, are nevertheless far from satisfactory. Although compiled from all available data, we have had hardly time enough to go into the subject with the thoroughness that it deserves, in order to sift out the tracks that represent the movements of cyclones unaccompanied by winds of any noteworthy violence, to omit everything founded too largely on guess-work, and to verify and correct the tracks of genuine hurricanes. As they stand, we cannot base upon them anything but the weakest and vaguest generalities.

A *hurricane* is an event of enormous importance in the history of atmospheric physics; to use a metaphor from human history, it is a great battle, upon which the fate of nations—of civilization itself—depends, as compared to the desultory and meaningless skirmishes that are so liable to confuse and mislead the historian. The simplicity and breadth of marine meteorology, due to the greater extent and uniformity of the leading meteorologic conditions at sea than on land, would seem to make its study of the very greatest value in arriving at any correct ideas regarding the general laws of atmospheric circulation, and to repay well the increased difficulty in collecting and collating data.

In a general way, then, these tracks illustrate the fact that hurricanes, originating as great whirlwinds in the tropics, move westward, northward, and finally northeastward, along

a parabolic track concave to the east, with a marked tendency to follow the Gulf Stream. Speaking of the origin of these terrific storms, Padre Viñes, the eminent director of the Observatory of Belen College, Havana, says:

"To the east of the Windward Islands and along the Caribbean Sea is planted a cyclonic battery which in certain months of the year aims its death-dealing projectiles at us—projectiles of incalculable destructive power and prodigious range." He says further, and to this I would call especial attention: "The position and aim of the battery that is planted to fire upon us, the range of its shots, and even the destructive force of its projectiles, all depend upon general causes that vary, more or less, with the seasons; hence the cyclone commonly takes a path that varies with the months."

Here, then, we have a general law, a key that opens the door to the solution of problems of the greatest interest and importance to the physicist, to the meteorologist, and to the practical navigator. Briefly stated, Viñes' laws regarding the recurvature of West Indian hurricanes are as follows: In June (and October) the vertex of the parabola is in about latitude 20° to 23° north; in July (and September), 27° to 29°, and in August, 30° to 32°. The importance of these laws is so great, both theoretically and practically, and the authority of their discoverer so well established, that they are worthy of the most careful consideration and are not to be denied on the strength of any series of storm tracks that has yet been published.

Let us consider next the conditions that precede the formation of a hurricane. To do this let us imagine ourselves aboard ship in the tropics, near the northern limits of the belt of equatorial rains and calms, and watch the weather. I will quote from "Two Years before the Mast," by R. H. Dana, Jr., a little book whose interest, truthfulness, and descriptive power are so great that many successive editions have been published since its first appearance, some fifty years ago:

"*Sunday, September 4th*, the trades left us, in latitude 22° north, longitude 51° west, directly under the tropic of Cancer. For several days we lay 'humbugging about' in the Horse latitudes, with all sorts of winds and weather, and occasionally, as we were in the latitude of the West Indies, a thunder-storm. It was hurricane month, too, and we were just in the track of the tremendous hurricane of 1830, which swept the North Atlantic, destroying almost everything before it. The first night after the trade-winds left us, while we were in the latitude of the island of Cuba, we had a specimen of a true tropical thunder-storm. A light breeze had been blowing from aft during the first part of the night, which gradually died away, and before midnight it was dead calm, and a heavy black cloud had shrouded the whole sky. When our watch came on deck, at twelve o'clock, it was as black as Erebus; the studding-sails were all taken in and the royals furled; not a breath was stirring; the sails hung heavy and motionless from the yards; and the stillness and darkness, which was almost palpable, were truly appalling. Not a word was spoken, but every one stood as though waiting for something to happen. In a few minutes the mate came forward, and in a low tone, which was almost a whisper, told us to haul down the jib. The fore and mizzen top-gallant sails were taken in in the same silent manner; and we lay motionless upon the water, with an uneasy expectation, which, from the long suspense, became actually painful. We could hear the captain walking the deck, but it was too dark to see anything more than one's hand before the face. Soon the mate came forward again and gave an order, in a low tone, to clew up the main top-gallant sail; and so infectious was the awe and silence that the clew-lines and buntlines were hauled up without any singing out at the ropes. An English lad and myself went up to furl it, and we had just got the bunt up when the mate called out to us something, we did not hear what,—but, supposing it to be an order to bear-a-hand, we hurried and made all fast, and came down, feeling our way among the rigging. When we got down we

found all hands looking aloft, and there, directly over where we had been standing, upon the main top-gallant mast-head, was a ball of light, which the sailors call a corposant (*corpus sancti*), and which the mate had called out to us to look at. They were all watching it carefully, for sailors have a notion that if the corposant rises in the rigging it is a sign of fair weather, but if it comes lower down there will be a storm. Unfortunately, as an omen, it came down and showed itself on the top-gallant yard-arm. We were off the yard in good season, for it is held a fatal sign to have the pale light of the corposant thrown upon one's face. As it was, the English lad did not feel comfortably at having had it so near him, and directly over his head. In a few minutes it disappeared, and showed itself again on the fore top-gallant yard; and, after playing about for some time, disappeared once more, when the man on the forecastle pointed to it upon the flying-jib-boom-end. But our attention was drawn from watching this, by the falling of some drops of rain, and by a perceptible increase of the darkness, which seemed suddenly to add a new shade of blackness to the night. In a few minutes, low, grumbling thunder was heard, and some random flashes of lightning came from the southwest. Every sail was taken in but the topsails; still, no squall appeared to be coming. A few puffs lifted the topsails, but they fell again to the mast, and all was as still as ever. A moment more, and a terrific flash and peal broke simultaneously upon us, and a cloud appeared to open directly over our heads, and let down the water in one body, like a falling ocean. We stood motionless and almost stupefied; yet nothing had been struck. Peal after peal rattled over our heads, with a sound which seemed actually to stop the breath in the body, and the 'speedy gleams' kept the whole ocean in a glare of light. The violent fall of rain lasted but a few minutes, and was followed by occasional drops and showers; but the lightning continued incessant for several hours, breaking the midnight darkness with irregular and blinding flashes. During all this time there was not a breath stirring, and we lay motion-

less, like a mark to be shot at, probably the only object on the surface of the ocean for miles and miles. We stood hour after hour, until our watch was out, and we were relieved at four o'clock. During all this time hardly a word was spoken; no bells were struck, and the wheel was silently relieved. The rain fell at intervals in heavy showers, and we stood drenched through and blinded by the flashes, which broke the Egyptian darkness with a brightness that seemed almost malignant; while the thunder rolled in peals, the concussion of which appeared to shake the very ocean. A ship is not often injured by lightning, for the electricity is separated by the great number of points she presents and the quantity of iron which she has scattered in various parts. The electric fluid ran over our anchors, topsail sheets and ties; yet no harm was done to us. We went below at four o'clock, leaving things in the same state. It is not easy to sleep when the very next flash may tear the ship in two, or set her on fire; or where the deathlike calm may be broken by the blast of a hurricane, taking the masts out of the ship. But a man is no sailor if he cannot sleep when he turns-in, and turn out when he's called. And when, at seven bells, the customary 'All the larboard watch, ahoy!' brought us on deck, it was a fine, clear, sunny morning, the ship going leisurely along, with a soft breeze and all sail set."

As a good, brief, scientific statement of the most widely accepted theory regarding the formation of these storms, Abbe's review of Blanford's results in the Bay of Bengal is of interest: "Cyclones are not produced between parallel currents flowing in opposite directions. A calm state of the atmosphere, or one in which the winds are light and variable over the open sea, is a favorable condition, and a second condition is a high or moderately high temperature," resulting "in the production and ascent of a large quantity of vapor, which will be condensed with the liberation of its latent heat over the place of its production. If this state of things last for some days, the slowly inflowing winds acquire by the influence of the motion of the earth a whirl, in consequence

of which, as Mr. Ferrel has shown, the barometric depression must increase. The last step preceding and apparently determining the formation of a well-defined cyclone in the Bay of Bengal is, according to Blanford, the inrush of a saturated stormy current from the southwest or west-southwest. But this last feature may be peculiar to that locality, and those previously enumerated seem to correspond best to the conditions generally observed in the formation of whirlwinds." Abbe says, further, "Concerning the origin and cause of the hurricanes of the Atlantic Ocean comparatively little is positively known." Relative to this statement it can only be said, I think, that it is one of the most remarkable and lamentable facts in the history of meteorology that we have so completely failed to utilize the admirable opportunities that exist for the study of marine meteorology. There is no large body of water in the world that compares with this in availability for such a purpose; it is classic ground for the meteorologist, for it was here that Redfield made his great discoveries; and, finally, very complete and reliable data have been for years past and are now being collected from masters of vessels navigating these waters. In spite of all these advantages, however, no well-directed effort seems to have been made to utilize the data at hand, and we have to go to the Bay of Bengal for light on the subject. The fact is, the interests of agriculture and other great inland industries are really so important in this country that they are of right entitled to every consideration; and yet commerce is a great factor in our success as a nation, and, indeed, the study of the meteorology of the Bay of North America is of the very greatest importance in connection with a knowledge of weather conditions in the entire eastern half of the United States, so intimate is the relation between the two.

Another theory regarding the formation of cyclones is that of the French astronomer, Faye, and this may be called the "descending eddy" theory. Although not supported by the same weight of authority as the generally accepted "aspiration" theory (referred to above), it seems to me to be worthy

of respectful consideration and comment, at least. Its essential feature is the hypothesis that eddies form amongst the rapid upper atmospheric currents and descend toward the surface of the earth, bringing down with them some of the intense energy of motion characteristic of their place of origin. The Edinburg Review for October, 1888, contained an able and favorable review of Faye's theory, going into the whole subject somewhat exhaustively. To one statement, however, I must take decided exception, and as it is rather an essential part of the theory I may as well quote it here. The reviewer says, after speaking of the comparatively clear and calm space at the center of a tropic cyclone: "There can, then, be no doubt that in the calm space of the typical storm of the tropics the air is descending; and if it be descending at the core, it is difficult, if not impossible, to believe that it is mounting in the spires." Relative to this statement I must say that it seems to me incredible that any one who has seen a tropic cyclone, or who has considered the known facts regarding cyclonic circulation, can fail to admit that there *is* an ascending current in the spires of the whirlwind. It is now well known that in a hurricane the winds at the surface blow somewhat spirally inward; the next upper current (bearing the low scud) moves in a circular direction about the center; the next higher (the high cumulus) in an outward spiral, and so on up to the very highest cirrus, which radiates almost directly outward. These features of cyclonic circulation are illustrated by means of this large chart, showing the marked spirally in-blowing character of the circulation in the great hurricane off our coast the 25th of last November, and by the cyclonoscope constructed by Padre Viñes to illustrate the typical and normal relative direction of motion of the various atmospheric currents, as observed by him in hundreds of cyclones. If, then, we are to believe the substantial accuracy of such data, there is no possible alternative but to accept the observed fact (regardless of any theory) that the air moves inward below, and, whirling about the central core, flows outward above.

One of the strongest arguments advanced against the theory of an ascending current has been the fact that all observations regarding the rainfall in a waterspout at sea have seemed to show that the water was *fresh*, and never *salt*, as it should be were any water drawn bodily up from the ocean. A recent and thoroughly reliable report sent to the United States Hydrographic Office from a vessel that passed through a waterspout off the Bahamas states positively that the rainfall was *salt water*, and this observation has been confirmed by careful inquiry regarding the particulars of the case. Admitting, then, that there is an ascending current of air in every cyclone, it does not seem to me that even this is sufficient to disprove the most essential feature of Faye's theory. In fact, if you start with the hypothesis of a descending eddy of cold dry air, the natural and normal result would be that an ascending spiral should be induced by it as soon as it broke through the intervening strata and reached down to the lower warm and saturated layers of the atmosphere. That there is a descending current of dry air at the center seems to be admitted, indeed, by the leading supporters of the "aspiration" theory, and the principal difference of opinion would therefore seem to be as to whether such a descending current or eddy be the *cause* or the *effect*. The following quotation from a late work by Ferrel must be of especial interest in this connection: "The air, charged with moisture, in its vertical circulation, in toward the center below, up in the interior to a given altitude, and outward above in the middle strata, necessarily moves in a path somewhat elliptical; so that it is being deflected outward above and still ascends until at a considerable distance from the center, and so there is little condensation of vapor in the central part, and the cloud stratum is thin and sometimes entirely wanting. And this state is still further promoted by the gyratory motion which is confined mostly to the lower and middle strata, bringing the air down from above, it may be, down pretty low, into the interior central part, where it is carried out horizontally on all sides; and the descending air in the

interior above is of course clear air. The effect under such conditions is a thinning of the cloud and a scantiness of condensation and rainfall in the center, a ring of denser and deeper cloud at some distance from the center, which gradually shades off to the outer limit. Where, however, the conditions give rise to a vertical or cyclonic circulation up to very high altitudes, this phenomenon is perhaps never observed." If the supporters of Faye's theory will only admit that their "descending eddy" must cause and be accompanied by spirally ascending whirls in the lower strata, then, perhaps, the "aspirations" will admit, on their side, that this theory, as well as their own, is competent to explain the facts. It would then remain to decide as to which of the two principles is the more general in its operation, and to discriminate, perhaps, between two classes of storms. There might, for instance, be reasons for believing that great hurricanes, traversing their majestic orbits for thousands of miles with such marked symmetry, individuality, and energy, may have a higher origin than the countless little storms whose more or less erratic tracks on our charts obscure their more regular and systematic paths.

It seems to me that there is one factor that has not received sufficient, if any, attention, namely, the focusing of the sun's rays at the center of a hurricane by reflection from surrounding cloud-masses and by refraction through strata of varying density about the "eye of the storm." Under certain conditions similar action may, perhaps, determine the *origin* of a hurricane, and certainly in the case of a fully developed hurricane, with a clear space at the center surrounded by a ring of piled-up masses of clouds, the reflected and refracted rays of an almost vertical sun must have a very great effect in determining the intensity, and variations in the intensity, of the storm.

What part electricity plays in maintaining the terrific energy of a hurricane is unknown. It is, perhaps, dimly suspected, for the problems of atmospheric electricity are engaging the attention of many of the ablest physicists of the

age, but it certainly has not as yet been announced. It is a striking fact that there is a marked absence of thunder and lightning in a tropic cyclone. The ordinary visible and audible manifestations of this great physical agent are almost wholly wanting in the inner whirls of a hurricane, although its pressure is indicated very decidedly in other ways. On *a priori* reasoning, at least, we must assign it some very important part in the phenomenon.

Certain marked exceptions to the normal tracks of hurricanes in the Bay of North America may next be referred to, and these I have illustrated by a chart upon which are plotted the tracks of two hurricanes of September, 1888, and two of September, 1889. Of the former, the first crossed Cuba from east to west, September 4th, and thence moved along a very abnormal track (about west by south) toward Vera Cruz; it was followed at a distance of about 700 miles by a second hurricane, which recurved about as usual. This notable exception to the usual law called forth an important statement from Padre Viñes, who attributed the deflection of the first hurricane to its *repulsion* by the second. The following extract from this statement may be quoted here: "At the impact of two cyclones the only currents that can and ought to produce a repellent action are the upper ones, which diverge from the center toward the circumference, and which are expelled with great velocity and to great distances in tropic cyclones. Consequently, when two meet, the upper currents of one flow out and strike the upper currents of the other directly. The lower currents, as they are convergent, tend rather to join the two cyclones in one. Furthermore, when two cyclones are brought into contact from a distance, the first meeting and first shock is among the upper currents, which extend much farther outward than the superficial winds. I would say, then, that the contact of the upper currents of the two cyclones could and ought to be proven, and that in fact the struggle was proven and established. We have, therefore, the exceptional case of a storm whose path, instead of curving toward the north, as usual, curved

southward, this rare phenomenon being due to the disturbing action of the upper currents of another simultaneous storm."

It has been observed that one hurricane often succeeds another and follows it at only a few days' interval and along an almost identical track. Probably in this case the relative position and normal motion of each happens to be such that the repellent action is manifested by accelerating the first and retarding the second. In addition to the interest that attaches to this question from the point of view of theory, there is thus a side of great practical importance, since occasion might arise when two tropic cyclones were known to be in existence near each other and it were desired to predict the course each would follow. This chart shows that a second and very severe cyclone was in existence about 800 miles east from St. Thomas, September 3, 1889, the very day that the first of these two September hurricanes passed the island. Now it seems possible, indeed, probable, that the delay of the first hurricane off our coast between Hatteras and Block Island was due to the area of high pressure built up between the two (as they moved north), southward of Newfoundland. Thus, just as in the case of the Cuban hurricane a year previously, the two cyclones modified each other's movements. It is so often the case that two storms of moderate energy unite to form one storm of considerable energy, especially in the temperate zone, that it seems particularly important to put on record the fact that two hurricanes repel each other. That this is not the case where cyclones of moderate or slight energy are concerned, even in the tropics, is evidenced by a recent communication from Maxwell Hall, Jamaica Government Meteorologist, who refers to the union west of that island of two small depressions that passed on either side of Jamaica September 15th. Here, then, is one distinction, at least, between the movements of cyclones of slight and great intensity, and it will serve to illustrate what was said relative to the importance of studying the movements of hurricanes from the tracks of hurri-

canes, and not from the tracks of cyclones of every grade of intensity. The case may be compared to that where the movements of great icebergs south of Newfoundland give correct ideas regarding the sub-surface currents that drag them southward into and through the easterly surface current, which, however, would determine the track of any lighter and less deeply immersed object.

The recent and very severe hurricane that was central off Hatteras September 8th, and that raged off the coast between Hatteras and Block Island for several days, is described briefly by a supplement issued with the October Pilot Chart, entitled "The St. Thomas-Hatteras Hurricane of September 3–12, 1889." The ten synoptic charts of the Bay of North America contained thereon illustrate the general characteristics of the storm for each day, from the time it passed St. Thomas till it died away north of Hatteras. Extracts from St. Thomas and Antigua newspapers illustrate the severity of the storm amongst the Windward Islands, and a chart of telegraph lines and cables shows that it is practicable, with the facilities that already exist, to get very complete telegraphic information regarding such storms, and to watch their progress from day to day as they approach our Atlantic and Gulf coasts. In the present case, indeed, brief telegraphic reports were received by the United States Signal Office, but the importance of early, decided, and definite warnings of such a storm would seem to require that we should receive as full reports as reach Havana, where the dangers of a hurricane are so keenly appreciated that the daily papers publish columns of news about every one that is reported from the Windward Islands. These long clippings from Havana newspapers show exactly what was known in Havana about this particular storm, as compared with the few words that reached Washington. The almost unfailing accuracy with which a skilled observer in the tropics can note the presence and character of a storm while it is still distant is not appreciated at all by those who are accustomed to base their forecasts entirely upon the syn-

chronous data charted on a daily weather map. This subject is so well understood at places like Manilla, Mauritius, and Havana, that a hurricane cannot come within 500 miles without detection by means of observations of the upper clouds, together with various other well-known indications, such as peculiar atmospheric effects, increased ocean swell, etc., although its existence might not even be suspected by the uninitiated. Indeed, a good example is furnished in the present case, where the motions of the storm were clearly traced from Havana when it was central about 900 miles away.

One very important source of information regarding a storm off the coast, generally recognized by meteorologic offices and published on their daily weather maps, in England and France, for instance, is the *state of the sea.* A long rolling swell from the direction of a distant storm is one of the earliest signs of its approach, and perhaps the very best index of its severity. This valuable source of information might well be utilized along our own coast. It will be remembered that it was a marked feature of the recent hurricane, and the enormous seas started by the great whirlwind had overspread almost the entire western half of the Atlantic as early as the 5th, when it was central 750 miles S SE. from Hatteras. At this time there was a heavy northeasterly swell at Jamaica and through the Windward Channel; northeasterly and easterly, all along the Bahama Islands and northern Florida; very heavy surf at Bermuda; long, rolling swell from S SE. off Hatteras, perceptible as early as the 2d and increasing daily; long, low southerly swell off Nantucket, perceptible as early as the 4th, when the storm center was 1,300 miles away, and increasing daily. The more severe the storm, the more important is this source of information. The energy of a hurricane is so concentrated that by the time its presence is indicated on a daily weather map by the increased velocity of the wind and low reading of the barometer the warning is too late to be of much value.

The high tides and floods along the coast between Hatteras

and Nantucket were due to the *storm wave* of the hurricane. This feature is well described in the following quotation from Buchan: "The most dreadful attendant on tropical cyclones is the storm wave, caused by the inflowing winds and the low pressure of the center of the storm. When this wave is unusually high and is hurled forward on a low-lying coast at high water it becomes one of the most destructive agents known. The Bakarganj cyclone of October 31, 1876, was accompanied by a wave which flooded the low grounds to the east of the delta of the Ganges to heights varying from 10 to 45 feet, by which more than 100,000 human beings perished."

In conclusion, permit me to call your attention to the commercial importance of the Bay of North America, the value to navigators and to the inhabitants of its shores and islands of taking advantage of every possible method of obtaining and circulating early and reliable information of approaching storms, and the admirable facilities that exist for the establishment by international co-operation of a weather service that would exhibit clear and intelligible storm warnings and concise general statements of existing weather conditions from every prominent light-house and headland. A cable is about to be laid from Halifax to Bermuda, which will add a very important station, and a line should be extended to Nassau, which is perhaps an equally important point. First and most important of all, however, the enormous value to commerce of a first-order station at Hatteras should be recognized, and this might well be considered in planning the new light-house on the outer Diamond Shoal. The great strategic value of this salient and commanding point in our outer line of defenses against Atlantic storms has never been fully appreciated. It is too often the case that at the first attack of the enemy the wire to Hatteras goes down and communication is severed. In connection with the new light-house there should be a cable that no storm, however severe, could ever interfere with. From a commercial point of view, at least, this is the central and

commanding point in the weather service of the Bay of North America.

Considering, then, what has already been said regarding the distance at which a skilled observer can note the presence and character of an ocean storm, it is interesting to take a map and select a certain number of points along the coast and from each of these points as a center describe a circle with a radius of, say, 300 miles (to be well within the distance assigned for the easy detection of an approaching storm). It will be found that an almost perfect system of interlocking circles can be obtained by selecting the following fifteen points, all of which, with the exception of Bermuda and Nassau, have, already, full telegraphic communication: Cape Race, Halifax, Nantucket, Hatteras, Bermuda, Nassau, Havana, New Orleans, Brownsville, Progreso, Kingston, St. Thomas, Barbados, Curaçao, and Aspinwall. A most important step toward the establishment of such a service has been taken by the formation at Havana of a Marine Meteorologic Service for the Spanish West Indies, under the direction of Captain Carbonell, of the Royal Spanish Navy, who has already rendered valuable assistance to the Signal Office and the Hydrographic Office. He has interested the French, Spanish, and American cable companies to such an extent that they have allowed him the franking privilege for his weather despatches over their lines, and it is hoped that the English company will soon grant the same favor, in consideration of the benefits that must result to commerce and to the people generally. With the growth and extension of this system we may expect to see, within a very few years, a great increase in the safety of navigation in the Bay of North America and a notable addition to our knowledge of every branch of marine meteorology.